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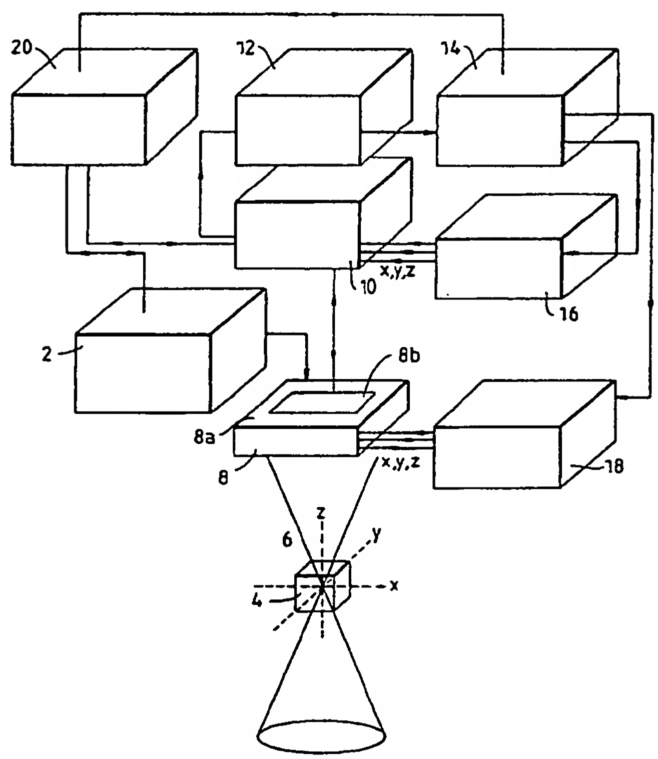
(54) Apparatus for speckle tracking in tissue

(57) An imaging device which uses "speckle" in interference pattern echoes received, in an imaging transducer 8b, back from ultrasound scanning of an organ, in order to follow movement of regions of tissue in that organ and thereby to monitor the position of a region of tissue which is to be treated. In use, successive echoes are received and their interference patterns are compared in order to determine the movement of a reference region. The movement and position of the region of tissue which is to be treated is then determined as a function of the determined movement of the reference region. This information can then be used to guide a lesioning device or other instrument involved in surgery.



At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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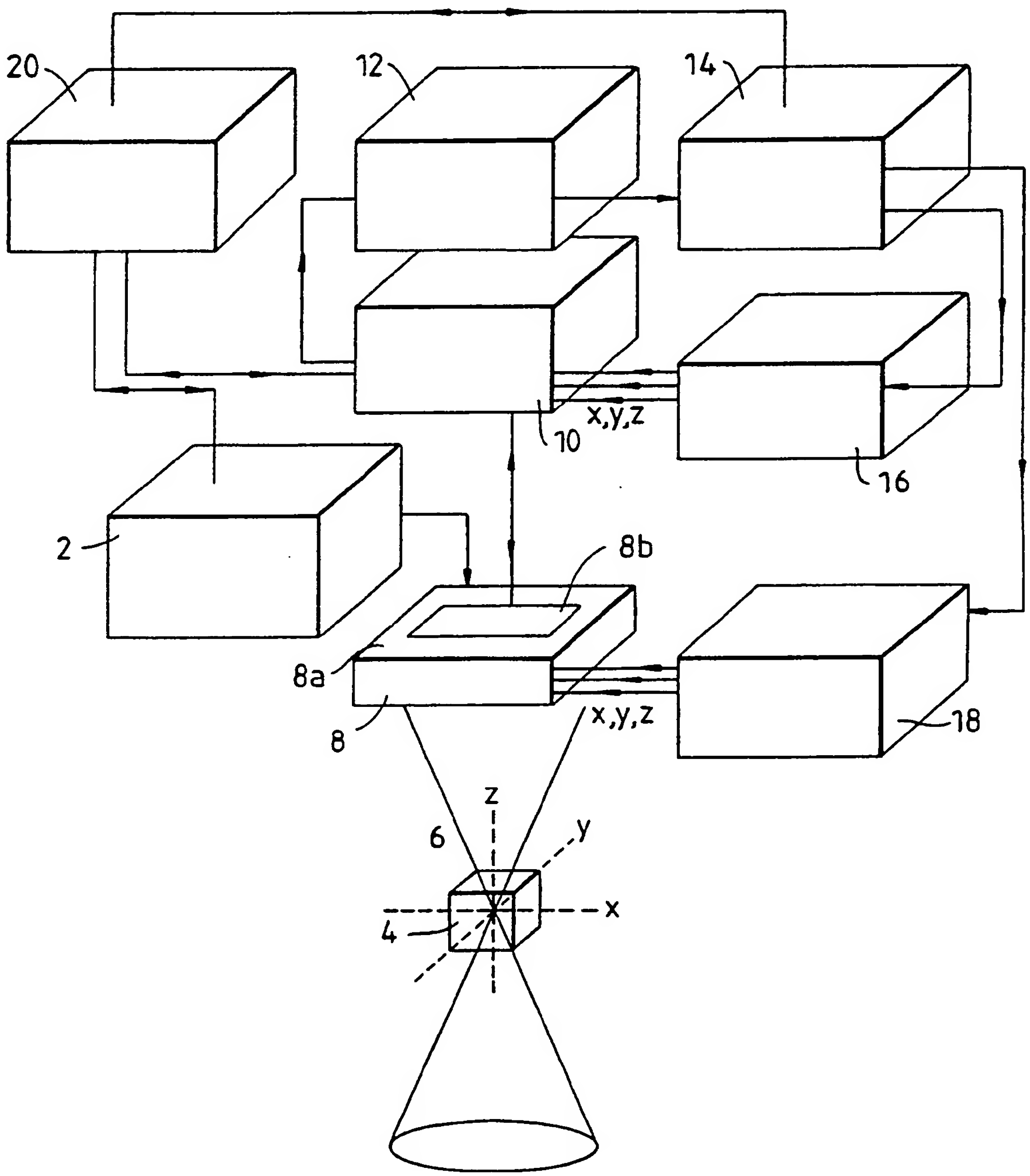
20
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"APPARATUS FOR SPECKLE TRACKING IN TISSUE"

The present invention relates to imaging apparatus for tracking movement of one area or region of tissue in an organ of a patient during remotely controlled surgical procedures, in order to monitor the position of that or another connected area of the organ. The need for such apparatus results from the fact that even when a patient is anaesthetised or unconscious, his internal organs are still moving as a result of normal functions such as heartbeat, or breathing. The invention makes use of a feature of imaging techniques using coherent radiation called "speckle" and enables a radiation beam, for example, to remain in correct alignment and range relative to a target area of tissue as it moves.

"Speckle" in an ultrasonic or other coherent radiation image, is an interference pattern that results from interaction between a target tissue and the coherent interrogating radiation.

Consider an ultrasonic imager scanhead, fixed in space and, repetitively and in a stable manner, obtaining two-dimensional sets of echoes from within a defined plane ("scan plane") through an object such as human tissue. The resulting display of echo amplitude will constitute a pattern that is to some extent representative of the internal structure of the object but which, in general, will also contain a substantial component of speckle artefact that derives from the coherent nature of the imaging radiation and which is, in a statistical sense, characteristic only of the design parameters of the imaging system.

If, between two interrogation cycles, there is movement of the object, there will in general be a corresponding change in the image pattern. Provided that such movement is sufficiently small, the change in the pattern will be such that specific similarities remain

between one pattern and the next: in mathematical terms the two sets of data are partially correlated. The changes between the two sets of data are, in principle, indicative of the direction and speed of the movement and the local extent and direction vector of such correlation may be calculated, if necessary for every point in the image plane. Thus, for this correlation and, in particular, for one initial point in the object and corresponding initial image plane, a subsequent movement history may be built up for a specific element of a tissue or other object, provided the recording of the echoes is continuous, or at least they are frequently sampled. This method is equally useful for three-dimensional as it is for two-dimensional scanning.

Use of speckle and speckle tracking is known in the determination of the velocity of blood-flow. It has also been used to determine the consistency of a tissue.

In non-invasive surgery, such as the use of ultrasound for the precise ablation or destruction of a region of tissue, a problem may arise if the target tissue moves during the course of the treatment. The movement might well be simply the result of respiratory or cardiac functions but it could lead to unintended treatment of non-target tissue, i.e. the destruction of good tissue, and the failure to treat some regions of target tissue which require treatment, and which, for example, could well include areas of cancerous cells which would then still be left behind. In order to effect adequate treatment, an excess of tissue, beyond what is necessary, must be ablated or destroyed. This, however, is never desirable and may sometimes be unsafe. Without making incisions into the patient it is difficult to determine to what extent the correct tissue has been treated. Alternative means of imaging tissue may not conveniently give sufficient resolution to be able to track particular areas, unless they are individual, well-defined, targets.

It is an aim of the present invention to provide apparatus which can be used in non-invasive surgery to alleviate, at least partially, the above mentioned drawbacks.

According to the present invention there is provided imaging apparatus for determining changes in the position of a target region of tissue in a body, said apparatus comprising:

emitting means for emitting radiation for irradiating at least one reference region of said body with coherent radiation;

receiving means for receiving radiation echoes from said at least one reference region;

means for comparing successive echoes to determine the movement of said at least one reference region using interference patterns in said echoes;

means for determining the movement and position of said target region as a function of said determined movement of said at least one reference region; and

directing means for directing one or more items to move in a way correlated to the determined movement and position of said target region.

Preferably, the irradiating and receiving means comprise a pulse-echo transducer, and more particularly, an ultrasonic imager scan head.

The invention relates to surgical apparatus using the above imaging apparatus to guide other instruments such as a lesioning device for ablating target areas.

The present invention will be further described by way of non-limitative example, with reference to the accompanying drawing, in which:-

The sole drawing is a schematic illustration of surgical apparatus including imaging apparatus according to the present invention.

The drawing shows, schematically, apparatus for guiding a spatially selective treatment device, such as a beam of focused ultrasound, within an organ such as the liver.

In this apparatus a source 2 of high-intensity sound, or ultrasound produces a therapy or treatment beam from a therapy transducer 8a in an array 8, the beam being focused at a target point 4. The same transducer array 8 contains a pulse-echo ultrasound imaging transducer 8b which is used to obtain echographic data of a reference volume 6 which is within the same organ and is therefore linked to the focal position 4. Echographic data from the imaging transducer 8b are transferred to a pulse-echo imaging device 10 where they are processed into 3-dimensional image data. These image data are then passed to a 3-dimensional image memory 12 and the contents of that memory 12 are used by a tracking processor 14 to determine the position of the reference volume 6, and thereby the movement and position of the target point 4. The processor then sends control signals to both an image position control and motor 16 and a focus position control and motor 18 which, respectively, control the position of the focus of the pulse-echo transducer through the imaging device 10, and the position of the focus of the therapy beam transducer 8a in the array 8. There is further a display and control panel 20 connected to the tracking processor 14, the pulse-echo imaging device 10 and the therapy beam signal source 2 so that the surgeon can monitor the whole process, as well as control it.

During surgery, or in preparation for it, the imaging transducer 8b emits a series of pulses at regular intervals and receives, in response, a series of samples of 3-dimensional sets of echo data from the selected reference volume 6, which are sent to the imaging device 10. The reference volume 6 consists of a region of tissue in one of a patient's organs. The therapy transducer 8a

is used to ablate target regions 4 of tissue in the same organ. The pulse-echo imaging device 10 controls the pulse-echo transducers to emit the radiation pulses and uses the received echo data to create 3-D images which are sent to the 3-D image memory 12. Successive images held in the 3-D image memory 12 are used by the tracking processor 14 which analyses the echographic data obtained at successive points in time to determine the movement of the reference volume 6 and thus the movement of the target region 4 which is to be treated. It does this using the speckle tracking process described in the introduction. The processor 14 uses this data to produce the control signals which are sent to the focus position control and motor 18 which guide the focus of the therapy beam to continue to follow the target point 4. Conventional methods and servos can be used to maintain the focus on the target point 4. Control signals are also sent by the tracking processor 14 to the image position control and motor 16 which similarly guide the imaging device so to follow the position of the reference volume 6 as it moves and to remain focused on it. The whole imaging device thereby follows tissue motion.

The surgeon can monitor this process through the display/control panel 20. He can determine when target tissue has been ablated for a sufficient length of time and readjust the therapy transducer 8a to focus on a new target point 4 which is then tracked in the same way as described above.

As an alternative to following a reference volume 6 of tissue as it moves around, speckle tracking processing can be used to calculate the spatial position, at any point in time, of a region of tissue that was initially at a selected spatial coordinate focused upon by the pulse-echo transducer but has since moved, with the transducer not moving its focus from that coordinate, using information from the new regions of tissue which

pass through that space. The information about the new spatial position of the tracked region is then used, as before, to readjust the aim of the therapy beam.

There may be more than one pulse-echo transducer able to obtain data on several such reference volumes 6. The transducers comprise a signal source and receiver, usually in pairs, which may be integral or each set at different positions. Pulse-echo transducers may be at totally different points from therapy transducers.

The focus of the therapy transducer can move around the organ in order to ablate regions as those regions move as well as being able to move from one region to the next. The focus of the imaging transducers can similarly move, as mentioned above, though that is not always necessary.

The local extent and direction vector of movement of tissue from the correlation between successive data from the echo receiver part of the pulse-echo transducer can readily be calculated in the tracking processor.

One factor which needs to be taken into account whilst implementing the present invention is that speckle tracking relies on statistical calculations and that without corrections the eventually computed positions of a reference volume will become subject to cumulatively increasing errors. To counter this the invention uses the fact that the actual movement patterns which in practice are going to be tracked will be cyclical, as a respiratory or cardiac function is cyclical, about an essentially fixed origin. The calculation algorithm used in the statistical processing can allow for this, modifying any calculated position by weighting it towards return to the appropriate chosen starting position.

If the target tissue, which requires treatment, is small enough then the original reference volume may be that area of tissue and only one pulse-echo transducer

will be necessary. However, it may be that the treatment is required for a substantially larger volume and this may be approached in various ways. In one approach, a valid assumption may be that tissue adjacent to that of interest will move parallel to and synchronously with the landmark volume, and again only one imaging transducer may be necessary. Alternatively, use may be made of two or more reference volumes, each of which is speckle tracked, and the instantaneous positions of intermediate tissue points can be interpolated through those of the reference volumes. The treatment beam may then follow the position of the intermediate tissue.

Although the invention has been described using a therapy beam to ablate target tissue it can be used to track tissue for other purposes such as, for example, for more precise imaging by using the apparatus to direct and move an imager to track tissue being observed.

CLAIMS

1. Imaging apparatus for determining changes in the position of a target region of tissue in a body, said apparatus comprising:

emitting means for emitting radiation for irradiating at least one reference region of said body with coherent radiation;

receiving means for receiving radiation echoes from said at least one reference region;

means for comparing successive echoes to determine the movement of said at least one reference region using interference patterns in said echoes;

means for determining the movement and position of said target region as a function of said determined movement of said at least one reference region; and

directing means for directing one or more items to move in a way correlated to the determined movement and position of said target region.

2. Imaging apparatus according to claim 1, wherein said radiation is ultrasound.

3. Imaging apparatus according to claim 2, wherein said emitting and receiving means comprise an ultrasonic imager scan head.

4. Imaging apparatus according to claim 1, 2 or 3, wherein said emitting and receiving means comprise a pulse-echo transducer.

5. Imaging apparatus according to any one of the preceding claims, wherein said comparing means uses correlations between a succession of "speckle" interference patterns to determine the movement of said at least one reference region.

6. Imaging apparatus according to any one of the preceding claims, wherein the focus of said emitting means follows said at least one reference region as that region moves.

7. Imaging apparatus according to any one of claims 1 to 5, wherein the focus of said emitting means is stationary and said emitting means irradiates reference regions which change with movement of said body.

8. Imaging apparatus according to any one of the preceding claims, wherein said emitting and receiving means irradiate and receive echoes back from two or more reference regions.

9. Imaging apparatus according to any one of claims 1 to 7, wherein said at least one reference region comprises said target region.

10. Imaging apparatus substantially as hereinbefore described with reference to the accompanying drawings.

11. Surgical apparatus comprising imaging apparatus according to any one of the preceding claims and an instrument for carrying out or assisting in the carrying out of a surgical procedure as an item whose movement is directed by said directing means.

12. Surgical apparatus according to claim 11, further comprising moving means for moving said instrument as directed by said directing means.

13. Surgical apparatus according to claim 11 or 12, wherein said instrument comprises a lesioning device for ablating said target region.

14. Surgical apparatus according to claim 13, wherein said lesioning device is an ultrasonic transducer.

15. Surgical apparatus according to claim 11, 12, 13 or 14, wherein said instrument includes a high resolution imager for imaging said target region.

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Examiner's report to the Comptroller under Section 17 (The Search Report) 10

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Relevant Technical fields

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(ii) Int Cl (Edition 5) G01S (15/89); A61B (8/12)

Search Examiner: VICKI STRACHAN

Databases (see over)

(i) UK Patent Office

(ii) ONLINE DATABASE: WPI

Date of Search: 10 SEPTEMBER 1993

Documents considered relevant following a search in respect of claims 1 TO 15

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
	NONE	

SF2(p) 1WL - doc99\fil000974

Category	Identity of document and relevant passages	Relevant to claim(s)
	-11-	

Categories of documents

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